MVA '96 IAPR Workshop on Machine Vision Applications, November. 12-14, 1996, Tokyo, Japan

Realization of Askant Glance Camera Vision System by Using Extended Hough Transform

Masafumi Tominaga * Kunihito Kato † Kazuhito Murakami * Hiroyasu Koshimizu *

* : School of Computer and Cognitive Sciences, Chukyo University

† : Department of Electronics and Computer Engineering, Faculty of Engineering, Gifu University

Abstract

We propose a new vision mechanism which can saccadicly move its fixation point for detecting straight lines within the image frame. This system, askant glance camera vision (AGCV) system, can extract straight lines precisely around the fixation point and rather coarsely at the periphery of the fixation point. This camera system works in such a way that the fixation point catches the moving object by the information of the center of gravity of edges, and the edges of the moving object can be extracted rather finely than the edges of the sleeping object. This system demonstrates a model of the center - fine / peripheral - coarse characteristics of human vision. This system is constructed by a sub-system which uses extended Hough transform functions and another sub-system which tracks an object and shifts its fixation point to the center of gravity. In this paper, we show some experimental results to show the performance of AGCV system.

1 Introduction

Generally in digital image processing, the features are extracted homogeneously in space even when the specific area or specific direction of the pattern in the image is interested in [1]. In order to realize a prototype system which has inhomogeneous characteristics for feature extraction [2], we are going to construct a mechanism, so - called " askant glance camera vision (AGCV) ", in this paper. As well known in the human vision, feature extraction is executed in such a way that lines are extracted precisely at the center of the glance and coarsely at the periphery. The outline of performance of AGCV is intended to realize just the same of this human vision especially by using Hough transform.

Although the AGCV system is an implementation of the central - fine vision system, we enforced this mechanism to introduce a dynamic tracking.

In this paper, we show the basic theory of the extended Hough transform (EHT), and introduce the basic configuration of AGCV system and how to track the moving objects in a manner of askant glance. Finally we present some experimental results to demonstrate the effectivity of the AGCV system.

Although this camera vision imitates sidelong glance, it is different from such a camera vision that pursues an object by moving its camera head. AGCV system extracts straight lines precisely around the fixation point and rather coarsely at the periphery of the fixation point in a software contrivance using an extended Hough transform (EHT) function.

In section 3, we show the basis theory of EHT function, and in section 4, we show an example of AGCV system which tracks moving objects. In section 5, the concept of the askant glance is extended to the angular sensitivity for line detection.

*Address: 101 Tokodate, Kaizu-cho, Toyota 470-03 Japan.
E-mail: tomy@koshi-lab.sccs.chukyo-u.ac.jp
† Address: 1-1 Yanagido, Gifu, 501-11, Japan.
E-mail: kkato@info.gifu-u.ac.jp

2 The Concept of AGCV System

We wish to compose the following AGCV system. AGCV system is one of the center - fine / peripheral - coarse camera vision systems that provides more extremely accurate recognition at the fixation point than at the periphery. This system is one of the realizing methods, which give more exact recognition at moving object around the fixation point. The concept of AGCV system to realize rather exact recognition of moving object around the fixation point is shown in Fig.1. Therefore, we must extract a fixation point, that is the center of gravity of moving object. We wish to realize a characteristic that is more precise perception at the fixation point. Then, we are realizing center - fine characteristics by an above idea.

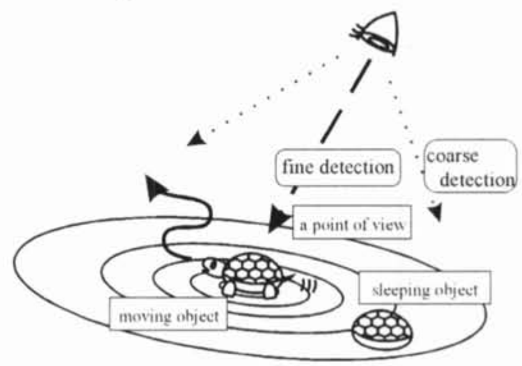


Fig.1 Concept of AGCV system.

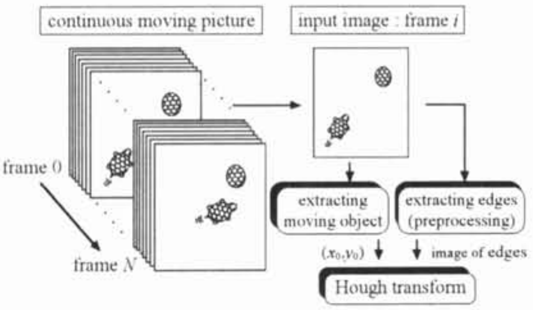


Fig.2 Diagram of tracking object.

AGCV system is made up of two parallel procedures, one is the detection of the center of gravity at the moving object and another is the detection of edge points as shown in Fig.2. The center of gravity of the moving object is detected by subtracting the background image from a set of continuous images, and the edge points for Hough transform are detected by Sobel, binarization, erosion, dilatation, and thinning operations.

Basing on these two procedures, we realized a dynamical central - fine / peripheral - coarse line detection without any modifications of the conventional camera and computer architectures.

3 Design of EHT for AGCV Systems

3.1 Conventional and Extended Hough Transform

A conventional Hough transform uses

$$\rho = x \cdot \cos\theta + y \cdot \sin\theta . \qquad (1)$$

In order to extend the functional expression of Hough transform, we have proposed the extended Hough transform (EHT) functions [3]. Since EHT function can be defined so that its new parameter space corresponds homeomorphically to (ρ,θ) space, it can be noted that specifying functional expression of EHT is equivalent to specifying sensitivity distribution of the parameter space. Let the EHT function be expressed by

$$g(\mu,\xi) = x \cdot f_1(\mu,\xi) + y \cdot f_2(\mu,\xi) . \qquad (2)$$

Parameters μ and ξ in eq.(2) give new parameters, one for a position and another for an angle (or orientation) of a straight line. In detail, the EHT function can be defined as the following conditions.

Condition-1 : $f_1(\mu,\xi)$, $f_2(\mu,\xi)$ and $g(\mu,\xi)$ should be a unique (single - valued) and continuous functions of the parameters μ and ξ, where $f_1^2(\mu,\xi)+f_2^2(\mu,\xi)\neq 0$.

Since $f_1^2 + f_2^2 \neq 0$, eq.(2) can be replaced by

$$\frac{g}{\sqrt{f_1^2+f_2^2}} = x \cdot \frac{f_1}{\sqrt{f_1^2+f_2^2}} + y \cdot \frac{f_2}{\sqrt{f_1^2+f_2^2}} \qquad (3)$$

and

$$R(\mu,\xi) = x \cdot \cos\phi(\mu,\xi) + y \cdot \sin\phi(\mu,\xi) . \qquad (4)$$

Condition-2 : $R(\mu,\xi)$ and $\phi(\mu,\xi)$ must be monotonously increasing (or decreasing) with respect to μ and ξ. Therefore,

$$\frac{\partial R(\mu,\xi)}{\partial \mu} > (or <) 0 \qquad \frac{\partial \phi(\mu,\xi)}{\partial \xi} > (or <) 0 \qquad (5)$$

must be satisfied.

Condition-3 : When the boundaries of ξ and μ are ξ_K , ξ_0 , μ_L and μ_0 ,

$$\begin{aligned} &|\phi(\mu,\xi_K) - \phi(\mu,\xi_0)| = \pi && for \ \forall\mu \\ &R(\mu,\xi_K) - R(\mu,\xi_0) = 0 && for \ \forall\mu \\ &R(\mu_L,\xi) - R(\mu_0,\xi) = B && for \ \forall\xi \end{aligned} \qquad (6)$$

must be satisfied as the boundary conditions, where B is given range of parameter ρ.

3.2 Warp Model of EHT

Suppose that two kinds of parameter spaces, (ρ,θ) and (μ,ξ), are digitized homogeneously into $L \times K$ cells. Since the domain for (ρ,θ) should be $0 \le \theta < \pi$ and $\frac{-B}{2} \le \rho < \frac{B}{2}$, and the domain of (μ,ξ) is $D \times C$, it is easily known that $\Delta\rho \cdot K : B = \Delta\mu \cdot L : D$. Therefore, the relations between the cell size of $\Delta\rho \times \Delta\theta$ and $\Delta\mu \times \Delta\xi$ can be given by

$$\Delta\rho = \frac{B}{D} \cdot \Delta\mu \qquad \Delta\theta = \frac{\pi}{C} \cdot \Delta\xi . \qquad (7)$$

Let the borders of cells be identified by (ρ_l, θ_k) and (μ_l, ξ_k) where $l = 0,1,2,\ldots,L$ and $k = 0,1,2,\ldots,K$.

The well-regulated cell array (μ_l, ξ_k) in (μ,ξ) space can be observed from the space (ρ,θ) as $(R(\mu_l,\xi_k), \phi(\mu_l,\xi_k))$. This can be observed as a skewed cell array in the (ρ,θ) space, called warp model of the transform function.

3.3 Designing AGCV Line Detector

Let S_ϕ be the fineness of resolution for the angular parameter ϕ and S_R be the fineness of resolution for the positional parameter R. Each one is defined by the ratios of $\frac{\Delta\phi}{\Delta\theta}$ and $\frac{\Delta R}{\Delta\rho}$, respectively, and we defined the measures for the fineness of resolution by

$$S_\phi = \frac{\partial\phi(\mu,\xi)}{\partial\theta} \qquad S_R = \frac{\partial R(\mu,\xi)}{\partial\rho} \qquad (8)$$

Since eq.(8) can be modified by

$$S_\phi = \frac{\partial\phi}{\partial\theta} = \frac{\partial\phi}{\frac{\pi}{C}\cdot\partial\xi} = \frac{C}{\pi}\cdot\frac{\partial\phi}{\partial\xi}$$
$$S_R = \frac{\partial R}{\partial\rho} = \frac{\partial R}{\frac{B}{D}\cdot\partial\mu} = \frac{D}{B}\cdot\frac{\partial R}{\partial\mu} \qquad (9)$$

based on the property given by eq.(7), the procedure to derive an exact expression of the EHT function can be expressed as follows.

(step1) Let the required fineness of resolutions be defined by giving the explicit functions of μ and ξ.

(step2) Let the differential equations given by S_ϕ and S_R in eq.(9) be solved under the constraint of the Condition-1, -2, and -3.

(step3) Let the solutions $R(\mu,\xi)$ and $\phi(\mu,\xi)$ be the explicit expression of the expected EHT function.

Let us suppose to design an EHT function of which the fineness of resolution for the angular parameter is constant and the fineness of resolution for the positional parameter is decreasing as being defined by

$$S_\phi = 1, \qquad (10)$$
$$S_R = 2\mu. \qquad (11)$$

The solutions

$$\phi(\mu,\xi) = \int S_\phi d\xi = \xi. \qquad (12)$$

and

$$R(\mu,\xi) = \int S_R d\mu = \mu^2. \qquad (13)$$

are the result. Thus, from this analytical result, it is important to note here that the fineness of resolution for the positional parameter to detect lines becomes fine around the origin of the pattern space when the transform function provided by

$$\mu^2 = x\cdot\cos\xi + y\cdot\sin\xi \qquad (14)$$

is used as the Hough transform function.

In order to realize a saccadic movement of the origin to the fixation point (x_0, y_0) in this Hough mechanism, a very simple shift operation of the coordinate system would be sufficient, and a new transform function

$$\mu^n = (x-x_0)\cdot\cos\xi + (y-y_0)\cdot\sin\xi \qquad (15)$$

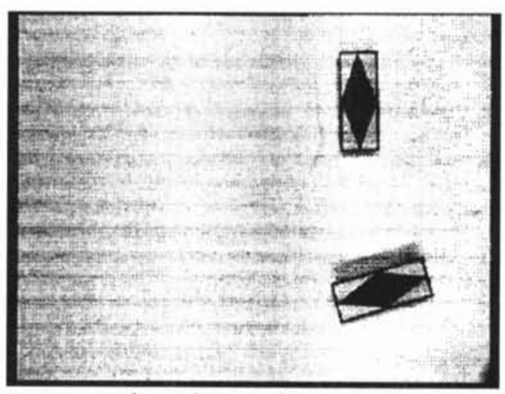
could be provided. In eq.(15), n is for the adjustment of sensitivity. This modification of the parameter space (μ,ξ) requires no augmentation of memory cost.

As a result, the Hough transform function, eq.(15), can provide a typical central - fine / peripheral - coarse characteristics for line detection.

4 Experiments and Considerations

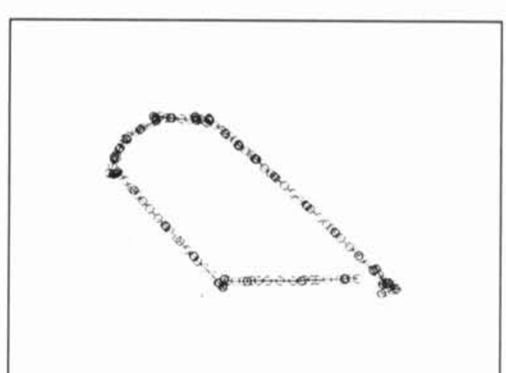
4.1 Experiments for Toy Cars Extraction

Figure 3 is an example image for AGCV system which tracks toy cars running on the floor. They have a texture of diamond pattern on the back. One is sleeping, and another is running around in the image. The number of image frames is 299. First, let the center point (x_0, y_0) of the running toy car be extracted. The locus of the center of gravity of the moving toy car is shown in Fig.4. And the each point of the locus is sent successively to AGCV line extraction module. The recognition of the moving object can be executed precisely as stated above. Fig.5 (a) shows the original gray image at frame 211. After extracting the edge points from original grey image, as shown in Fig.5 (b), they are processed by AGCV system together with the information (x_0, y_0). As shown in Fig.5 (c), the line patterns on the running toy car were precisely extracted, and those on the sleeping toy car were not sufficiently extracted. Fig.5 (d) shows the result of segmentation for each straight lines [3] [4].



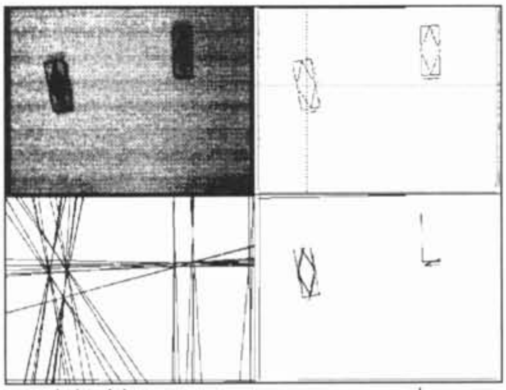
(a scene of continuous images ; frame 001)

Fig.3 An image of the moving toy cars used for the experiment.



(One toy car, existing at the lower part of the image in Fig.3, is moving, and another one is sleeping.)

Fig.4 The locus of the moving car.



(a) original image
(b) extracted edges
(c) extracted lines
(d) running toy car extracted in higher resolution

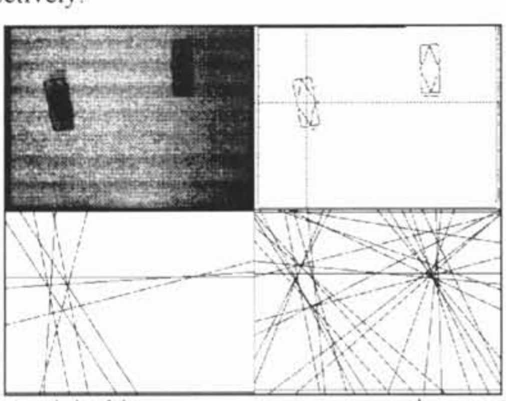
(a)	(b)
(c)	(d)

Fig.5 Results of tracking moving toy car by AGCV system (frame 211).

4.2 Comparative Experiments

We can expect that the recognition of lines around the fixation point would become precise even when the size of the parameter space is restricted, because AGCV system has a characteristic of recognizing precisely around the fixation point. Then, we compare the AGCV with a conventional method which uses usual Hough transform function of which parameter size is 100×100. Fig.6 (a) is the original image of frame 210. And Fig.6(b) is the extracted edges. Fig.6 (c) and (d) are the extracted lines by AGCV and by a usual Hough transform, respectively.

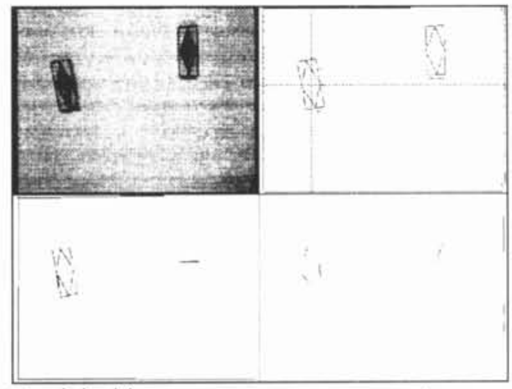
Fig.7 shows the result of segmentation for the extracted straight lines. Fig.7 (a) is the original image, and Fig.7 (b) is the extracted edges. Fig.7 (c) and (d) are the result of segmentation for the lines extracted by AGCV and a conventional Hough Transform, respectively.



(a) original image
(b) extracted edges
(c) lines extracted by AGCV
(d) lines extracted by conventional Hough transform

(a)	(b)
(c)	(d)

Fig.6 Results of AGCV compared with a conventional Hough transform (frame 210).



(a) original image
(b) extracted edges
(c) lines extracted by AGCV
(d) lines extracted by conventional Hough transform

(a)	(b)
(c)	(d)

Fig.7 Results of segmentation of lines (frame 210).

5 Fine Line Detection at specified Angle
– an extended askant glance –

In the same way, the above center fine detection system by modifying positional sensitivity, we apply the same concept to the specified angle [5]. Now we pay attention to the detectional sensitivity of angle. Then, S_ϕ defined by

$$S_\phi = -m \cdot \cos 2(\xi - r) + 1 \qquad (16)$$

is an example for the periodically continuous sensitivity characteristics. r is the angle for the higher sensitivity. m is an adjustment parameter of angle sensitivity. Hough transform function,

$$\phi(\mu, \xi) = \int S_\phi d\xi = -\frac{m}{2} \cdot \sin 2(\xi - r) + \xi + C \qquad (17)$$

is given by solving eq.(16). Furthermore, eq.(17) becomes

$$\phi(\mu, \xi) = \int S_\phi d\xi = -\frac{m}{2} \cdot \sin 2(\xi - r) + \xi \qquad (18)$$

by C=0. The sensitivity of line detection by this EHT function (eq.(18)) is shown in Fig.8.

As shown in Fig.9, for the original image which is generated by random noise, the lines directed for r (= 0° ,45° ,90°) are likely to be extracted by the respective transform function with the parameters r (= 0° ,45° ,90°). Consequently, we could confirm that the fine line detection of direction of the specified angle was realized.

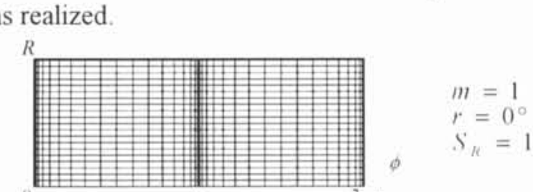
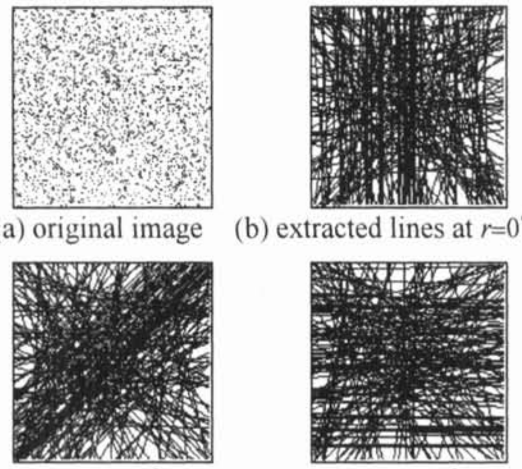


Fig.8 Parameter space (Warp Model) of EHT function.



(a) original image (b) extracted lines at $r=0^\circ$

(c) $r=45^\circ$ (b) $r=90^\circ$

Fig.9 An example of experiment to detect lines of specified angle.

6 Conclusion

This paper proposed the AGCV system by means of warp model of the extended Hough transform (EHT). This camera vision system was confirmed to be robust by a few experiments. From our experiments, it was confirmed that AGCV system could realize a prototype of central - fine / peripheral - coarse of human vision to pursue a running object precisely. In addition to this, we proposed to apply AGCV concept to the fine line detection at specified angle. Future works are as follows. The AGCV system has to be reduced in processing time. An adaptation of this AGCV system to plural moving objects in the image is expected to extend the applicabilities. Furthermore we would like to find some practical application also of the extended askant glance vision.

Acknowledgement

This paper was partially supported by Grant - in - Aid for General Scientific Research (No.08207222, No.07680415, No,08780313, 1996). We would like to express thanks to these supports.

References

[1] Hough, P.C.V. : "Method and means for recognizing complex patterns", U.S.Patent, 3069654 (1962).

[2] Toshikazu Wada, Makito Seki, Takashi Matsuyama : "High Precision $\gamma-\omega$ Hough Transform Algorithm to Detect Arbitrary Digital Lines", Trans.IEICE, Vol.J77-D-II, No.3, pp.529-539 (Mar. 1994) (in Japanese).

[3] Kato, K., Murakami, K. and Koshimizu, H. : "On a segmentation algorithm of lines of Hough transform using discriminant analysis", Proc.MVA'94, (Kawasaki) (Dec.1994).

[4] Kato, K., Murakami, K. and Koshimizu, H. : "Segmentation Algorithm of Lines of Hough Transform using Discriminant Analysis", Proc.ACCV'95, vol.III, pp.191-195 (Singapore) (Dec.1995).

[5] Tominaga, M., Kato, K., Murakami, K., and Koshimizu, H. : "An extention of Hough transform function and its application to the askant glance camera vision", Proc. of MIRU'96, vol.II, pp.313-318 (July.1996) (in Japanese).